REMARKS

This amendment responds to an Office Action bearing a mailing date of February 16, 2006 and the Notice of Non-Compliant Amendment bearing a mailing date of April 27, 2006.

Election/Restriction

In paragraph 1 of the Office Action, the examiner stated that applicant's election of invention of Group I, claims 1, 2, 4, 5, 13, 14, 17, 19, 21 and 23 in the reply filed on November 30, 2005 is acknowledged.

Specification

In paragraph 2, the examiner stated that the abstract of the disclosure is objected to because it is not a single paragraph and because the phrase "are disclosed" is in line 2. Applicant has drafted a replacement abstract and enclosed it herewith. It is believed that the abstract is in the proper language and format as the examiner set forth in paragraph 3 of the Office Action.

Objection to the Disclosure

In paragraph 4 of the Office Action the examiner objected to the disclosure because of a number of informalities. Applicant has corrected the informalities set forth in paragraph 4 of the Office Action.

Objection to Claims Because of Informalities

In paragraph 6 of the Office Action the examiner stated that claims 1, 2, 4, 5, 13, 14, 17, 19, 21 and 23 were objected to because of a number of informalities. Applicant has amended these claims to correct the objections set forth by the examiner.

Claim Rejections – 35 USC Section 112

In paragraphs 7 and 8 of the Office Action the examiner stated that claims 1, 2, 4, 5, 13, 14, 17, 19, 21 and 23 are rejected under 35 USC Section 112 for failing to comply

with the enablement requirement. Applicant has amended these claims to correct the deficiencies set forth by the examiner in order to comply with the enablement requirement.

In paragraphs 9 and 10 of the Office Action the examiner stated that claims 1, 2, 4, 5, and 23 were rejected under 35 USC Section 112, second paragraph, as being indefinite. Applicant has amended claims 1, 2, 4, 5, and 23 to correct the indefinite phrases within these claims and to make them definite.

Claim Rejections – 35 USC Section 103

In paragraphs 11 through 14 of the Office Action the examiner has rejected the claims under 35 USC Section 103(a) as being unpatentable over Loutfy et al. (US 2003/0082074 A1) in view of Withers et al. (US 5876684) and either Wong et al. (US 5288969) or Cheung et al. (US 6517913 B1).

Applicant respectfully disagrees that either Loutfy alone or Loutfy in view of Withers, Wong or Cheung combined disclose applicant's invention for the reasons given herein below.

Applicant's Invention

Applicant's invention primarily is an electroheat device, in which electric energy is converted into heat for a useful purpose. Applicant's invention synergistically uses two different electrothermal techniques to heat a graphite element, these being induction heating and inductive plasma heating.

In the induction heating, an alternating electromagnetic field induces electric eddy currents in a load, this being a graphite element, that is heated by the Joule effect.

The inductive plasma heating is a method of heating using thermal plasma as a heat source and in which ionization is obtained by excitation of a gas in a high frequency electromagnetic field.

In applicant's invention, a graphite element is moved toward an inductor coaxially positioned along the movement axis. The inductor is powered by a high frequency generator to produce a strong high frequency electromagnetic field around and mostly in the core of the graphite element. When the strong, high frequency electromagnetic field

envelops the graphite element, the element begins to heat intensively due to the powerful internally induced eddy currents. Subsequently, the temperature of the element rapidly increases and a graphite vaporization process occurs. This occurs in the presence of an inert gas which is supplied to the chamber containing the graphite element and flows around the graphite element. Consequently, the same high frequency electromagnetic field both causes a continuous graphite vaporization and triggers and maintains an inductive high temperature plasma. The hot plasma settles itself partially inside and beyond the inductor, enfolding the heated graphite element that is facing the inductor and providing a supplemental energetic contribution to sustain intense vaporization of the graphite element.

With such temperatures and the related conditions, suitable plasma resistivity values are obtained, where the high frequency electromagnetic field is still able to sufficiently penetrate into the graphite element to continue its heating and vaporization actions. This is entirely different from a plasma torch device.

Thus, as seen from the above, in applicant's invention both induction heating and inductive plasma heating work simultaneously to obtain a fundamental advantage in the production of carbon nanotubes. This occurs because the graphite vapors leaving the vaporizing element are immediately immersed into a high temperature plasma where the thermodynamic environment is favorable for subsequent formation of nanotubes and their derivatives.

<u>Loutfy et al. (US 2003/0082074 A1)</u>

Loutfy's invention is directed to a radio frequency plasma method and device for producing nanotubes, but there are two important differences between the Loutfy device and applicant's device. Loutfy's device is made up of an inductor powered by a high frequency generator <u>surrounding</u> a vacuum chamber with an inlet port and an evacuation port, and utilizes a powder feeder for <u>feeding powder</u> into the vacuum chamber. In addition to the evident differences where the Loutfy device utilizes an inductor powered by a frequency generator outside of the vacuum chamber and uses a powder as opposed to a graphite element, the heating method used by the Loutfy device also is different from that of applicant.

Loutfy claims and exclusively uses an inductively coupled plasma torch (ICP) to obtain a hot plasma able to vaporize thin and appositely prepared powders. In particular, Loutfy states (col. 5, paragraph 0036), "Ultrafine solid carbon or coal (1-5 μm size) was required to vaporize all of the carbon based materials in the short residence time employed in operating this reaction". In other words, in the described Loutfy device only very subtle and thin powders could feed the plasma torch (in a similar way to the so-called Laser Ablation – ICP methods, where an intense laser spot ablates off powders from a sample that is leaded to a plasma torch to be ionized and analyzed by optical or mass spectrometric methods).

The use of a plasma torch forces the inductor to be out of the vacuum chamber (the inductor can not be put into the chamber where presence of conductive powders would cause electric discharge between inductor coils, preventing the plasma ignition).

From the above, it may be seen that Loutfy's device is different in form and substance from applicant's device and it is clear that Loutfy's powders could not be used in applicant's devices since high frequency eddy currents cannot circulate effectively in thin dispersed powders to cause carbon vaporization. Of course, applicant's solid graphite elements could not be used in Loutfy's device. In fact, Loutfy's device was invented for powders only, where first the gas is heated to a plasma ignition and then the plasma vaporizes the coal or graphite powders.

It is obvious to one having ordinary skill in the art that if a solid graphite element was inserted in Loutfy's device the frequencies that would be necessary to heat the gas and maintain a plasma are far higher than frequencies used in induction heating. These high frequencies heat the plasma at very high temperature where an almost total ionization occurs. With such ionization, the hot plasma is sufficiently conductive that eddy currents would inductively circulate in a very thin depth of plasma and only in a minimal fraction in a conductive element immersed in such plasma, a fraction insufficient to have a sufficiently intense heating to cause vaporization.

The working frequency used in applicant's device and set forth in new claim 25 is sufficient to have an inductive heating of the solid conductive graphite body and only then, at graphite vaporization temperature sufficient to maintain a plasma that, at the used frequencies, does not allow strong eddy currents in itself that could shield the graphite

element from the coil electromagnetic field, to continue the induction beating of the graphite, and, at the same time, keeping the plasma sufficiently hot to favor the formation of nanotubes and fullerene.

Based on the above, it may be seen that the device disclosed in the Loutfy publication is entirely different from that of applicant.

Loutfy also does not disclose a second inductor powered by a second high frequency generator as disclosed by applicant and set forth in claim 2 of the instant application.

Loutfy et al. (US 2003/0082074 A1) in view of Withers et al. (US 5876684)

Withers appears to disclose a device similar to that of Loutfy for producing only fullerene in Fig. 6 of the drawings. The drawings disclose an inductor powered by a high frequency generator surrounding a reactor having an inlet and outlet, with a similar atmospheric condition, and where a solid rod may be fed into a vacuum chamber.

The specification states that "Fig 6. is a schematic representation of another form of the system of Fig. 1 wherein the heating source comprises an induction plasma type system" and "Fig. 10 is a schematic representation of another form of the system of Fig 6. wherein the heating source comprises a microwave source to induce plasma". These two statements confirm that principally, as in Loutfy et al., Withers uses a plasma heating system to vaporize the carbon particulate feed illustrated in Fig. 6.

Once again, in Fig 6., the induction coil 52 is shown surrounding the quartz reactors 51 as opposed to applicant's device where to maximize the electromagnetic coupling and to increase total efficiency, the coil must be as close as possible to the load and, consequently, must be inside the chamber.

Col. 7, line 37 of Withers states the quartz reactor 51 confines "the quenching gas in the heated reaction zone" which indicates a further difference with respect to applicant's invention where there is no restriction on the flow of the inert gas necessary to obtain the end product.

Withers et al. in col. 8, line 1 states "a solid carbon rod or plates or the like can also be vaporized by the induction, microwaves or higher frequency power generation system." However, the referenced device is still the same as depicted in Fig. 6, and,

therefore, a device different from that of applicant's invention. In Fig. 6 of the Withers device, it is stated that the quartz reactor 51 is water-cooled. Applicant's vacuum chamber is not water-cooled. Prior to developing the instant invention, applicant experimented with a device having a solid bar in a water-cooled quartz tube and a coil surrounding the tube encoupling the bar. With this configuration, it was learned that the vaporized carbon suddenly condensed on the inner wall of the quartz tube causing a dense black film deposition. Since the temperature of the graphite is more than 3000°C and the radiation power from the graphite element surface could reach 1kW/sqcm, the radiation is intercepted by the black deposit and the quartz temperature rapidly increases to the quartz melting point, which destroys the apparatus.

Additionally, Withers did not disclose a device using simultaneously "induction heating" and "inductive plasma heating".

Neither Loutfy nor Withers and Loutfy combined teach applicant's invention.

<u>Loutfy et al. (US 2003/0082074 A1) in view of Wong et al. (US 5238969) or Cheung et al. (US 6517913 B1)</u>

Wong shows an inductive coupled RF plasma torch (Fig 2) where a coil may be positioned internal or external of a chamber wall and Cheung discloses a plasma cleaning apparatus comprising an inductively coupled plasma source with a coil placed either inside or outside a vacuum chamber (Fig. 11 and col. 22, lines 15-17).

The apparatuses of both Wong and Cheung again are related to a gas heated up to plasma formation. The heat sources are <u>hot plasma torches</u> in which waste materials (Wong) or hazardous gases (Cheung) are dissociated (Wong) or reduced (Cheung). Applicant's device is different because the heat source is the graphite itself that is inductively heated by eddy currents to its vaporization point.

As states above, in connection with Loutfy's device, it was demonstrated that any device fundamentally conceived as an inductively coupled RF plasma torch is different from applicant's invention that is based on induction heating applied to a solid element plus a convenient plasma having a lower temperature than a plasma torch. Loutfy itself demonstrated that with a plasma torch only thin graphite or coal powders can be

profitably used to produce nanotubes. In fact, the use of the Loutfy device is not applicable to solid elements.

The apparatuses of Wong and Cheung are fundamentally conceived to destroy waste or hazardous gasses, so the thermodynamic environment in both inventions is primarily suited for this purpose: a plasma with high ionization and electron dissociation that interacts with mater since dissociation or reduction of waste molecules is used to obtain more elemental and less hazardous compounds. On the other hand, applicant's invention is committed to the formation of compounds, fullerenes and nanotubes, structurally comparable or even more complex than precursor graphite. This is due to the fact that in applicant's invention the thermodynamic environment created by induction heating in synergy with a cooler plasma is dramatically less severe than in a plasma torch. If the coils used in Wong and Cheung's devices would be used in applicant's device, the inductively created plasma induced by the coils inside or outside of the chamber walls would cause destruction of the precursor material. Only if thin powders, as in Loutfy's patent, are introduced in the plasma torch could nanotubes be produced. But again, this is not the case in applicant's invention.

Moreover, the coils use and represented in the Wong and Cheung' drawings are different from the coil used in applicant's invention.

In Wong Fig. 2, the RF power source 76 powers "two helixes 66, 68 where they are joined together at ends 80 adjacent the second and third points. Current flows from the source 76 in the direction of the arrows from the ends 80 to the opposite ends 82, 84 of the helixes that are connected to ground potential adjacent the first and fourth points." (col. 5, lines 5-12) It is evident that in Wong's invention there are two coils and, moreover, the current flow in the coils is in opposite directions (see arrows in the connection point 80). Furthermore, the ends 82, 84 are connected to ground potential to close the circuit with power source 76.

In applicant's invention, the coil is a different, single pass through by one current and, most importantly, created for simultaneous presence of induction heating and thermal plasma creation. Moreover, the coil is intentionally kept floating from ground potential.

Wong affirms in the summary of his invention (col. 2, lines 45-55) "The waste material is combined with a controllable source of free electrons, and the RF plasma torch is used to excite the free electrons, rising their temperature to 3000°C or more. The electrons are maintained at this temperature for a sufficient time to enable the free electrons to dissociate the waste material as a result of collisions and ultraviolet radiation generated in situ by electron-molecule collisions. The source of free electrons is preferably an inert gas such as argon, which may be used as both the waste material carrier gas and the torch gas."; and again (col. 6, lines 29-33) "The non-thermal nature of the dissociation process of the present invention can be illustrated by the fact that the waste material temperature can remain in the range of 300°C to 1,000°C while being bombarded by free electrons at temperatures of 10,000°C."

If one, in hypothetical manner, having ordinary skill in the art at the time the invention was made would use the Wong coils applied to Loutfy's invention with a solid graphite element, instead of powders for which Loutfy's device was created, it would establish a non-thermal plasma, as declared above, with temperatures in the solid element remaining well under the 3000°C temperature necessary for carbon vaporization.

Cheung's coils are different. He states (col. 21, lines 54-56) "To properly resonate the coil, it is important that the length of the coil be about or slightly longer than ¼ of the wavelength of the applied RF signal" and (col. 23, lines 4-7) "Because the length of the coil should be slightly longer than ¼ of the RF wavelength, there is a direct relationship between the coil length and RF frequency used. Longer coils require lower frequency RF power signals."

Loutfy states in the summary of the invention (page 6, paragraph 0042) as a preferred example, "This powder mixture is fed into the reactor (20-mm diameter)"; moreover, in Example 3 (page 8, paragraph 0064), Loutfy states "the reactor was a 20 mm inner diameter quartz tube, the created plasma ball was constrained within 10 cm^3." A simple geometric calculation shows the approximate length of such plasma ball: $L = V/\pi * r^2 = 10/3.14 = 3.18$cm.

Being that the plasma cannot contact the quartz walls, it is plausible to estimate that the length of the Loutfy coils could be around 5cm. Calculating with Cheng's tuning criterion, the wavelength has to be 4 times the inductor length, or around 20cm, which

corresponds to a working frequency of about 1500 MHz. With this order of magnitude of the frequencies, the "depth of penetration δ" of induced current in the ionized plasma, that is, expressed in meters $\delta = 503(\rho/f)^{\wedge 1/2}$ (where resistivity ρ is between 10^{-4} ohm*m and 10^{-2} ohm*m for a thermal plasma and frequency "f" is in Hz) is from 0.13mm to 1.3mm.

Even if one chooses an inductor 20 times longer (i.e., one meter) than what was indicated by Loutfy as a preferred example, the "depth of penetration δ" would range between 0.57mm to 5.7mm. It is evident that also in this extreme value the shielding effect appears as above.

If one, in a hypothetical manner, having ordinary skill in the art at the time the invention was made, would use Cheung's tuning criterion for coils applied to Loutfy's invention with a solid element inside, independently from the coil being inside or outside the chamber walls, also considering different dimensions, not taking into account that the frequencies are not, in any case, suitable for induction heating, the shielding effect of the thermal plasma, due to low "depth of penetration δ", would avoid the penetration of field lines and the induction heating of solid graphite element by eddy currents. Again for Fig. 11, Cheung reports "A coil 152 is wound around the exterior of tube 150 and connected to an RF power supply at one end at point 156 and connected to a ground potential at the other end point 155".

It is easy to see in Fig. 11 of Cheung that said coil is a <u>three terminal coil</u>, with one terminal grounded (155), a second working terminal (156) which position has been selected in order to tune the coil with the necessary impedance (see col. 22, lines 31-35), and the third terminal is kept free in order to realize the tuning operation. Therefore, independently from the possibility of winding the coil 152 within the interior of the tube 150 (col. 22, lines 15-17), the described device is again different from applicant's invention, where the coil is a <u>two terminal non-tunable coil</u>, and, as stated above, is intentionally kept floating from ground potential.

The choice to have the coil totally insulated from ground potential is substantial for the function of applicant's invention. In applicant's device, the products, nanotubes and nanostructured carbon particles, are directed toward the evacuation port, but a small portion is diffused around the chamber and the coil. If a coil with a terminal connected to

ground would be used in applicant's apparatus, possible conductive chains may be formed by condensed nanotubes conductive particles. If one end of the coil would be grounded, the formation of a second path for currents toward ground potential would short circuit the coil and cause sever discharges, compromising the operation of the device. In applicant's invention this cannot happen because the coil floats with respect to ground.

If the same materials (nanotubes and nanostructured carbon particles) were present in the Wong and Cheung devices that were both invented for different purposes, having the coil connected to ground with a terminal, a second possible connection to ground through chains of carbon nanoparticles would short circuit the coil and stop the process.

In summation, Loutfy discloses a device having an inductor powered by a high frequency generator surrounding a vacuum chamber into which a powder is fed. Loutfy also discloses heating with an inductively coupled plasma torch. Wong and Cheung disclose the use of hot plasma torches as a heat source for destroying hazardous waste materials.

Neither Loutfy alone nor in combination with Wong and/or Cheung disclose applicant's device of producing nanotubes, fullerene and their derivatives where a graphite element within a vacuum chamber having an inductor therein powered by a high frequency generator is heated by the electromagnetic field generated by the inductor. Additionally, applicant's invention discloses that an inert gas is introduced onto the vacuum chamber around the graphite element to form a plasma.

Based on the above, neither the Wong nor Cheung devices alone or in combination with the Loutfy device disclose applicant's invention and in fact, could not be combined in any way to function in the same manner as applicant's disclosed and claimed invention, as set forth above.

Applicant respectfully submits that Claims 1, 2, 4, 5, 13, 14, 17, 19, 21, and 23 and new Claim 25 now are in condition for allowance and such action respectfully is requested.

Respectfully submitted,

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